EFFECT OF CRUMB RUBBER ON MECHANICAL PROPERTIES OF TERNARY 
BLENDING CONCRETE

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ABSTRACT

Cement Concrete is most widely used material for various constructions. Increased use of various ingredients of concrete for construction works has lead to the immense scarcity of natural materials like sand, stone etc. Added to this, in the recent past, growing environmental problem due to excess production of solid waste materials like fly ash and silica fume has tempted many researchers to try these materials as concrete ingredients. Also, the disposal of used tyres has become a tough task. Therefore, in this paper, it is proposed to investigate the effect of crumb rubber on strength characteristics of Ordinary Portland Cement (OPC) Concrete and Ternary Blended Concrete (TBC) of M40 grade with fly ash and silica fume as powders along with cement. The mechanical properties of TBC in fresh and hardened state are studied and compared with that of OPC Concrete.

KEYWORDS: Crumb Rubber, Fly Ash, Silica Fume, Ternary Blended Concrete, Mechanical Properties, Impact Strength

INTRODUCTION

Solid waste management has been a major environmental concern in cities around the globe. Recent studies indicate that roughly 4.6 billion tons of nonhazardous solid waste materials are produced annually in the United States among which waste tyres constitute a significant portion. It was predicted that approximately 400 million waste vehicle tyres were collected in India by the end of the year 2009. Wasted or abandoned tyres are not easy to decompose. The simplest way to get rid them is by burning, but this method generates many problems and pollution due to smoke. Therefore, the burning method is unacceptable and in some countries it is prohibited by law. An easier solution is to leave them piling up on empty lands, which indirectly generates several other problems because they simply turn into fire sources or insect and animal habitat.

Because of the above problems, more and more attention has been paid to use waste vehicle tyres in Portland cement concrete as waste aggregate. As concrete has become the most widely used construction material in the world, the partial addition of rubber tyre particles into concrete would consume billions of scrap tyres. Moreover, the use of rubber tyres in concrete could improve the ductility and toughness of the material apart from providing a permanent solution for disposal of this waste material. Therefore, successful use of the material in concrete could not only provide a promising solution to the environmental problem, but also gives us a material with some improved properties due to its high energy absorption characteristics.

Eldin and Senouci (1993) reported that concrete mixtures with tyre chips and crumb rubber aggregates exhibited lower compressive and splitting tensile strengths than regular PCC. There was approximately 85% reduction in
compressive strength and 50% reduction in splitting tensile strength when coarse aggregate was fully replaced by coarse crumb rubber chips. However, a reduction of about 65% in compressive strength and up to 50% in splitting tensile strength was observed when fine aggregate was fully replaced by fine crumb rubber. Both of these mixtures demonstrated a ductile failure and had the ability to absorb a large amount of energy under compressive and tensile loads Khatib and Bayomy (1999). Topcu (1995) also showed that the addition of coarse rubber-chips in concrete lowered the compressive strength more than the addition of fine crumb rubber.

However, results reported by Ali et al (1993), and Fattuhi and Clark (1996) indicated the opposite trend. Studies have indicated that if the rubber particles have rougher surface or given a pretreatment, then better and improved bonding may develop with the surrounding matrix, and, therefore, that may result in higher compressive strength. Pretreatments may vary from washing rubber particles with water to acid etching, plasma pretreatment and various coupling agents (Naik and Sing1991). In acid pretreatment, rubber particles are soaked in an alkaline solution (NaOH) for 5 minutes and then rinsed with water. This treatment enhances the strength of concrete containing rubber particles through a microscopic (a very small) increase in the surface texture of the rubber particles.

Eldin and Senouci (1993) soaked and thoroughly washed rubber aggregates with water to remove contaminants, while Rostami et al. (1993) used water, water and carbon tetrachloride solvent, and water and a latex admixture cleaner. Results showed that concrete containing water washed rubber particles achieved about 16% higher compressive strength than concrete containing untreated rubber aggregates, whereas this improvement in compressive strength was 57% when rubber aggregates treated with carbon tetrachloride were used.

Herna´ndez-Olivares et al. (2002) found that the addition of crumbed tyre rubber volume fractions up to 5% in cement matrix does not imply a significant variation of the concrete mechanical properties. Skid resistance is found to increase with rubber content and large particle rubber seemed to provide better skid resistance. However, the crumb rubber concrete block performed poorer than plain concrete block in terms of abrasion resistance (Piti Sukontasukkul and Chalermphol Chaikaew, 2005). Increase in rubber content increases the air content, which in turn reduces the unit weight of the mixtures (Tung-Chai Ling and Hasanan, 2006).

Gintautas, et al. (2007) concluded from their investigations that rubber additive added at 1% of the concrete volume reduces the compressive strength by average of 4%, the bending strength by average of 2.4% and the tensile splitting strength by average of 0.9%. Sallam, et al. (2008) concluded that the replacement of fine aggregate by crumb rubber to the extent of 10% caused no appreciable decrease in concrete compressive strength. The presence of crumb rubber of small size in concrete increased the resistance of concrete to crack initiation under impact load. The rubber of small size had no particle bridging effect, hence, the mode of failure of rubberized concrete under static and impact compression was the same as that of plain concrete.

The effect of silica fume addition on the compressive was more obvious in the case of rubberized concrete compared to plain concrete. El-Gammal, et al. (2010) observed a significant reduction in the compressive strength of concrete when the tyre rubber was used to replace the aggregate in the concrete mixtures. However, during testing of the specimens, a significant amount of compressibility was observed allowing the specimens to absorb a large amount of energy under compressive loads. Camille (2010) found that enhanced ductility and damping properties of rubber can better be used in highway barriers or other similar shock-resisting elements as rubber absorbs vibration to a large extent. Gintautas, et al. (2010) concluded in their paper that the addition of rubber waste to cement matrix increases the porosity of the matrix due to the air-entrainment in the fresh concrete. Improvement in mechanical performance was observed by Sara
Sgobba, et al. (2011) in rubcrete mix with latex coating of the particles surface, probably due to its waterproof action. Addition of rubber to concrete resulted in a more ductile failure. This behavior indicates that these types of concretes have higher strength and better energy adsorption capability (Mohammad Reza sohrabi and karbalaie, June 2011).

SIGNIFICANCE OF THE WORK

The present work aims at the study of impact of crumb rubber on the mechanical properties of TBC in fresh and hardened state and to compare the same with the OPC concrete. Fly ash and silica fume are used in TBC as partial replacement of cement. It is known from the literature that the introduction of crumb rubber in concrete improves energy absorption characteristics of OPC concrete. Hence, in the present study, crumb rubber powder is used in TBC to improve energy absorption characteristics of concrete. Thus, by using fly ash, silica fume and crumb rubber in concrete, environmental problem of disposal of these waste materials can be solved to some extent.

EXPERIMENTAL INVESTIGATION

The present experimental work is carried out to study the mechanical properties of M40 grade concrete using ordinary Portland cement concrete and ternary blended cement concrete with varying percentages of crumb rubber.

Materials Used for Investigation

Cement: Ordinary Portland cement of 53 grade, with Specific gravity 2.90 and Consistency 32%, was used,

Fine Aggregate: The locally available natural river sand confirming to grading zone-II of tables 4 of IS 388-1970 with specific gravity is 2.604has been used as fine Aggregate.

Coarse Aggregate: Machine crushed granite confirming to IS: 383-1970 consisting of 20 mm maximum size of aggregates has been obtained from the local quarry. It has been tested for Physical and Mechanical Properties such as Specific Gravity, fineness modulus and its specific gravity is found is 2.665.

Fly Ash and Silica Fume: Fly ash is obtained from National Thermal Power Corporation at Kothagudem in Andhra Pradesh. Silica fume is obtained from the Elkem India Pvt Ltd Company, Navi Mumbai. Physical properties of fly ash and Silica fume are shown in Table 1.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Normal Consistency</th>
<th>Specific Gravity</th>
<th>Fineness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30%</td>
<td>2.23</td>
<td>2.4%</td>
</tr>
<tr>
<td>2</td>
<td>35%</td>
<td>2.11</td>
<td>2.0%</td>
</tr>
</tbody>
</table>

Water: Locally available potable water is used.

Super Plasticizer: Conplast SP-430 from fosroc chemicals is used as super plasticizer.

METHODODOLOGY

Eight batches of concrete were cast of which four batches is made of M40 grade using crumb rubber with various percentages (0%, 5%, 10% and 15%) and remaining four batches were made of M40 grade ternary blended concrete with various percentages of crumb rubber (0%, 5%, 10% and 15%). Optimum percentages of silica fume and fly ash in ternary blended concrete were obtained by making number of trials starting from 5% silica fume and 15% of fly as partial replacement of cement.
Optimum mix was arrived at by considering the compressive strength. Six cubes, three cylinders, three prisms and three discs were cast corresponding to each batch of concrete to determine the compressive, tensile, flexural and impact strengths of concrete. Cylindrical discs with 150 mm diameter and an average depth of 63 mm were tested for Impact strength. The test was carried out according to ACI: 544.

**TEST RESULTS AND DISCUSSIONS**

The results of the investigations are shown in tables 2 to 4

**Workability and Density**

The workability of TBC is found to be more compared to OPC concrete for all percentages of crumb rubber content (Figure 1). There is a decrease in workability of concrete as percentage of crumb rubber increased from 0% to 15% in OPC concrete as well as TBC. However, the workability is more in TBC compared to OPC concrete. The density of concrete also decreased as the crumb rubber content increased due to the fact that its density is very less (Figure 2). But the reduction in density is more in OPC concrete than TBC concrete which may be due to the presence of fine particles like fly ash and silica fume in TBC.

**Compressive Strength**

Compressive strength decreased as the percentage crumb rubber increased in both OPC as well as TBC concretes. The maximum loss in compressive strength at 7 days and 28 days are 20 and 32.5% respectively in OPC when 15% of crumb rubber is used (Table 2). The maximum loss in compressive strength at 7 days as well as at 28 days is about 37% in TBC when 15% of crumb rubber is used. But the reduction in compressive strength of concrete at 28 days age with 5% of crumb rubber is only 15.9% in OPC and 12.7% in TBC (Figure 5).

The strength reduction may be attributed to the entrapped air which increased with the rubber content. Also, during the vibration of concrete samples, rubber particles move toward the upper surface of the mould resulting in a high concentration of rubber particles at the top layer of the specimens.

This is due to the lower density of rubber materials compared to the other ingredients of the concrete. Thus, non-uniform distribution of rubber particles at the top surface and the entrapped air might contributes to the reduction in strength.

**Split Tensile Strength and Flexural Strength**

The percentage loss in split tensile strength increased from 13.7% to 32.4% as crumb rubber content increased from 5% to 15% in OPC concrete at 28 days age while the same for TBC concrete increased from 13.6 to 31.6% (Figure 7). Similar trend was observed in flexural strengths also with an increase in loss of strength from 24 to 54% for both OPC and TBC concretes as the crumb rubber increased from 5 to 15% (Figure 6).

**Impact Strength of OPC and TBC**

The impact energy absorbed by OPC and TBC concretes with various percentages of crumb rubber are given in Table 3. This clearly shows the increased energy absorption characteristics of crumb rubber concrete.

The toughness of the material increases to about 2 times in OPC concrete and 3 times in TBC just by adding 5% of crumb rubber in concrete. The increase in energy absorption in OPC concrete and TBC is nearly 8 times, compared to plain concrete, as the crumb rubber content increased to 15% (Figure 8).
Table 2: Variation of Compressive Strength of Concrete

<table>
<thead>
<tr>
<th>Mix ID</th>
<th>Compressive Strength (N/mm²)</th>
<th>Percentage Loss of Compressive Strength (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 Days</td>
<td>28 Days</td>
</tr>
<tr>
<td>OPCC</td>
<td>31.80</td>
<td>50.22</td>
</tr>
<tr>
<td>OPCC-CR5</td>
<td>28.77</td>
<td>42.20</td>
</tr>
<tr>
<td>OPCC-CR10</td>
<td>27.22</td>
<td>36.60</td>
</tr>
<tr>
<td>OPCC-CR15</td>
<td>25.48</td>
<td>33.89</td>
</tr>
<tr>
<td>TBCC</td>
<td>37.24</td>
<td>51.76</td>
</tr>
<tr>
<td>TBCC-CR5</td>
<td>30.20</td>
<td>45.20</td>
</tr>
<tr>
<td>TBCC-CR10</td>
<td>27.20</td>
<td>35.50</td>
</tr>
<tr>
<td>TBCC-CR15</td>
<td>23.50</td>
<td>32.60</td>
</tr>
</tbody>
</table>

Table 3: Variation of Number of Blows and Energy Absorbed at First Crack and Ultimate Failure

<table>
<thead>
<tr>
<th>Mix ID</th>
<th>Number of Blows Required</th>
<th>Energy Absorbed (KN-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At First Crack</td>
<td>At Ultimate Crack</td>
</tr>
<tr>
<td>OPCC</td>
<td>74</td>
<td>81</td>
</tr>
<tr>
<td>OPCC-CR5</td>
<td>137</td>
<td>152</td>
</tr>
<tr>
<td>OPCC-CR10</td>
<td>469</td>
<td>483</td>
</tr>
<tr>
<td>OPCC-CR15</td>
<td>1000</td>
<td>1013</td>
</tr>
<tr>
<td>TBCC</td>
<td>234</td>
<td>241</td>
</tr>
<tr>
<td>TBCC-CR5</td>
<td>641</td>
<td>656</td>
</tr>
<tr>
<td>TBCC-CR10</td>
<td>989</td>
<td>1015</td>
</tr>
<tr>
<td>TBCC-CR15</td>
<td>2076</td>
<td>2097</td>
</tr>
</tbody>
</table>

Figure 1: Variation of Workability of Fresh Concrete Due to the Addition of Crumb Rubber

Figure 2: Variation of Density of Fresh Concrete Due to the Addition of Crumb Rubber
Figure 3: Variation of Split Tensile Strength of OPCC and TBCC Due to the Addition of Crumb Rubber at 28 Days

Figure 4: Variation of Flexural Strength of OPCC and TBCC Due to the Addition of Crumb Rubber at 28 Days

Figure 5: Percentage Loss of Compressive Strength of OPCC and TBCC Due to the Addition of Crumb Rubber at 28 Days

Figure 6: Percentage Loss of Flexural Strength of OPCC and TBCC Due to the Addition of Crumb Rubber after 28 Days

Figure 7: Percentage Loss of Split Tensile Strength of OPCC and TBCC Due to the Addition of Crumb Rubber after 28 Days

Figure 8: Variation of Energy Absorbed for OPCC and TBCC Due to the Addition of Crumb Rubber at Ultimate Failure
CONCLUSIONS

- The introduction of crumb rubber into fresh concrete decreased the workability of concrete marginally and also the compaction factor was decreased as the percentage of crumb rubber increased in all concrete mixes (Figure 1).

- The low specific gravity of the crumb rubber in concrete resulted a decrease in the unit weight of the concrete by 2.16% for 5% addition of crumb rubber, by 5.15% for 10% and by 7.43% for 15% compared to ordinary Portland cement concrete.

- There is a marginal reduction in compressive strength with 5% addition of crumb rubber in ordinary Portland cement concrete and ternary blended cement concrete. Compressive strength drops drastically when the crumb rubber content increases beyond 5% and the concrete becomes unfit to be used in structural elements.

- There is a tremendous increase in the impact energy of crumb rubber concrete compared to plain concrete. Though there is a decrease in compressive strength by about 10 to 15%, the increase in impact strength is 100% in case of concrete with 5% crumb rubber for both OPCC and TBC.

- By visual observation during experimentation, it was found that the crack widths in crumb rubber concrete are less compared to concrete without crumb rubber in both ordinary Portland cement concrete and ternary blended concrete.

- In a country like India, scrap tyres can be easily incorporated in concrete as a construction material where vibration damping is required such as foundation pads for machinery, and runways and taxiways in the airport.

REFERENCES


